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Numerical Study of a Three-float Wave Energy Converter - M4

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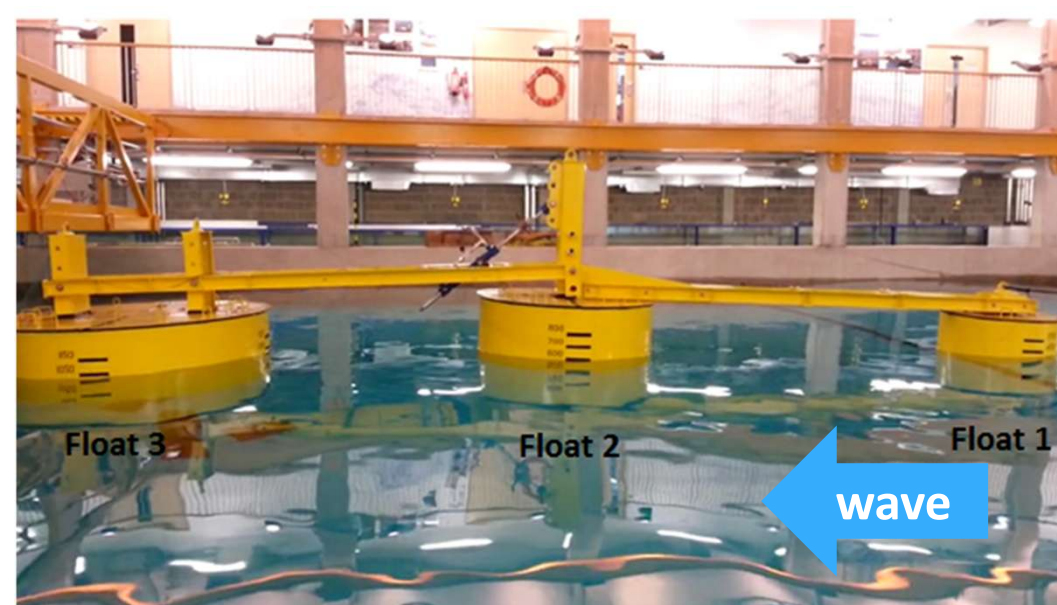
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Introduction

Researchers at the University of Manchester have developed a moored, three-body line absorber - M4 that can extract wave energy from various modes of relative motions (surge, heave and pitch) between the floating bodies [1]. In the present EPSRC funded project Step-WEC (Step change for wave energy conversion through floating multi-body multi-mode systems in swell), a potential-flow solver DIFFRACT [2] has been further developed for assessing the performance of M4 in uni- and multi-directional waves. Both hydrodynamic interactions and mechanical connections between the three floats of M4 have been considered by using a two-stage approach [3]. The power take-off (PTO) system is simplified as a linear rotational damper. Drag damping associated viscous effects have been calculated using Morison's type formula. Numerical results of mean power absorbed by M4 have been compared with experimental data.

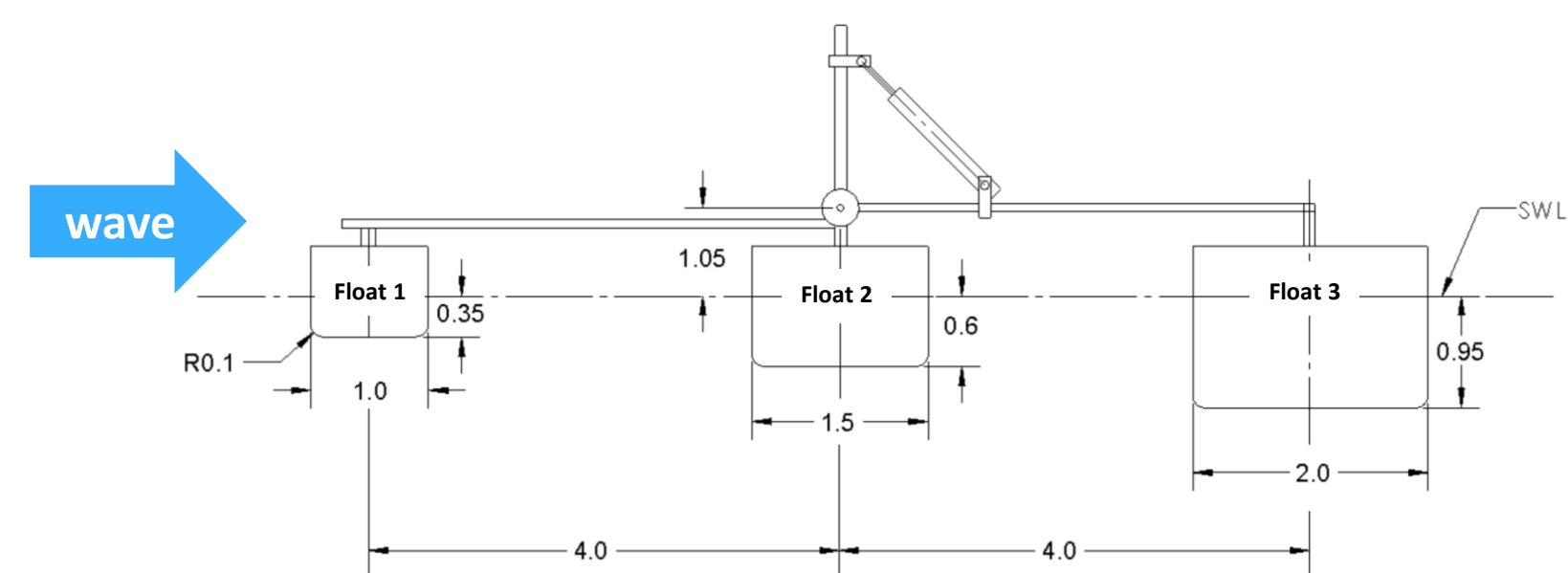
Results and Discussions

M4 Testing in the Plymouth Ocean Basin (1:8 Scale)

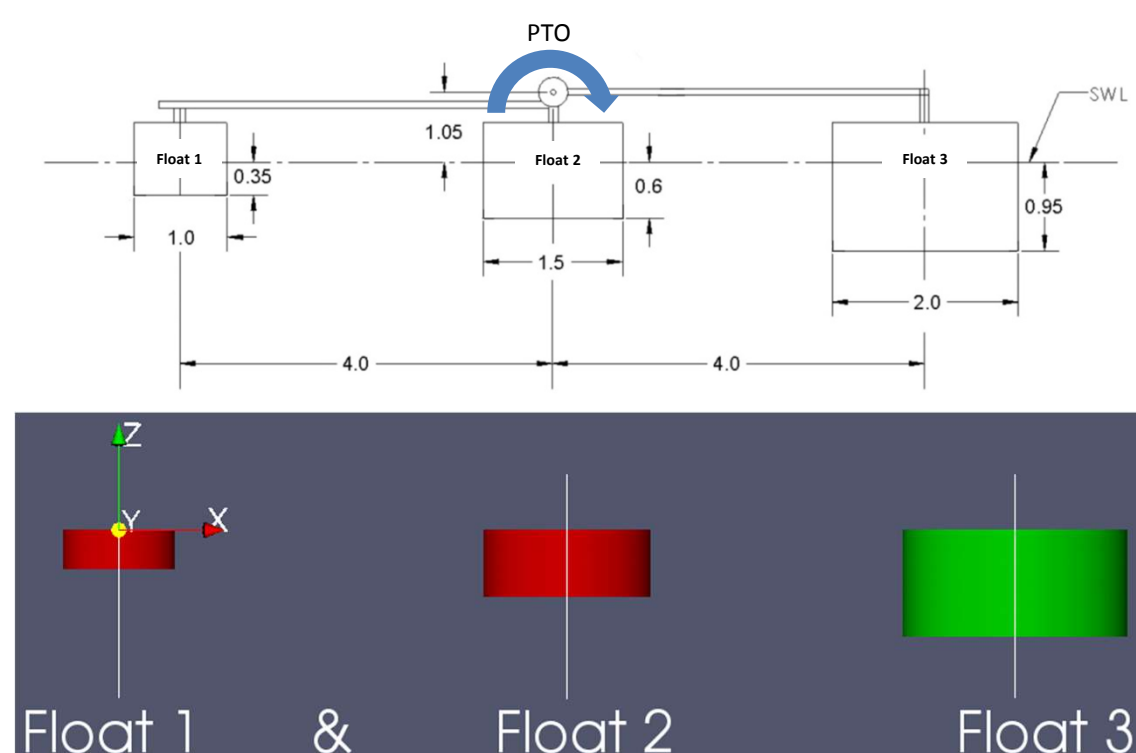


Experiments at 1:8 scale were undertaken in the University of Plymouth wave basin using floats with flat bases. The radius of curvature of the rounded bases corners was 0.1m and water depth was 2.9m. In tested model of M4, float 1 and 2 were rigidly connected by a horizontal beam. There was a single hinge above the float 2 connecting stern float 3 with another horizontal beam. The PTO system consisted of three hinges, two beams and a hydraulic cylinder with piston above float 2. Experimental studies showed that high crest capture widths of wave energy conversion can be achieved across a broad band of frequencies and the peak capture widths are greater than 25% of a wavelength in regular waves [1].

Configurations of Model Test (Unit: m)



Numerical Model in DIFFRACT



In the numerical analysis of M4, three floats have been modelled as truncated cylinders with sharp corners at the bottoms. Float 1 and float 2 have been considered as one combined body. The PTO system has been simplified as a linear rotational damper.

Calculations of Drag Damping and Mean Captured Power

Linearized drag forces have been calculated in the present frequency-domain analysis, where C_d is drag coefficient, ρ is water density, A is frontal area, \vec{v} are velocities of water particles in undisturbed wave, $\vec{\xi}_f$ are velocities of frontal areas

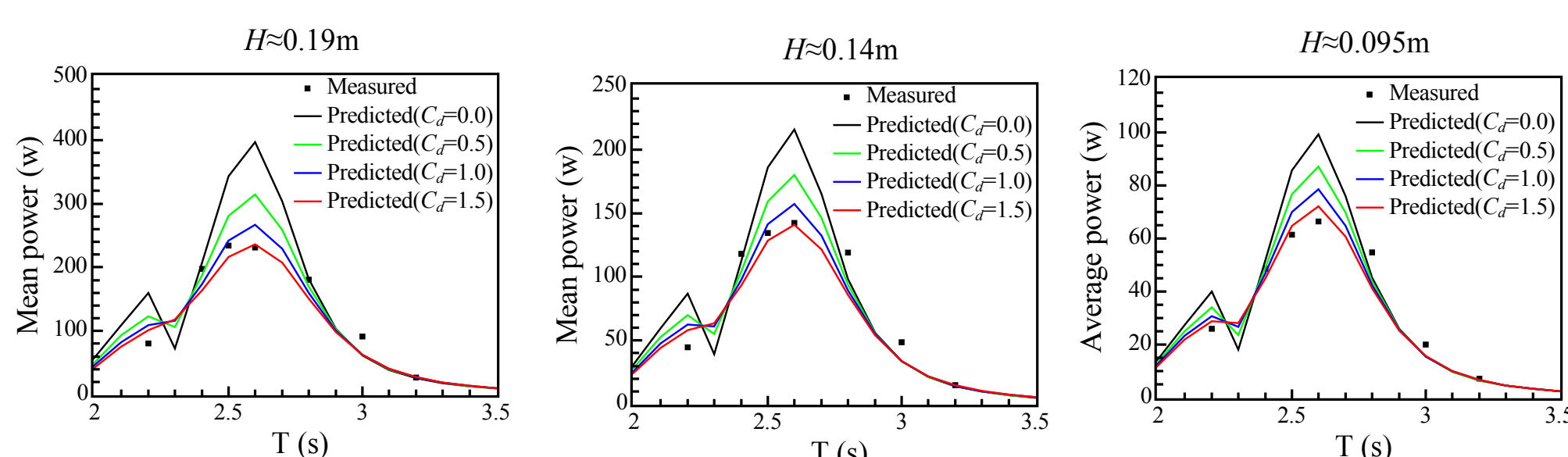
$$F_d = 0.5C_d\rho A \left(\vec{v} - \dot{\vec{\xi}}_f \right) \left| \vec{v} - \dot{\vec{\xi}}_f \right| \frac{8}{3\pi}$$

When the PTO system is presented by a linear damper, the mean power captured by wave energy converter in regular waves of frequency ω can be given by

$$P = \frac{1}{2} \omega^2 B_{PTO} |\theta_r|^2$$

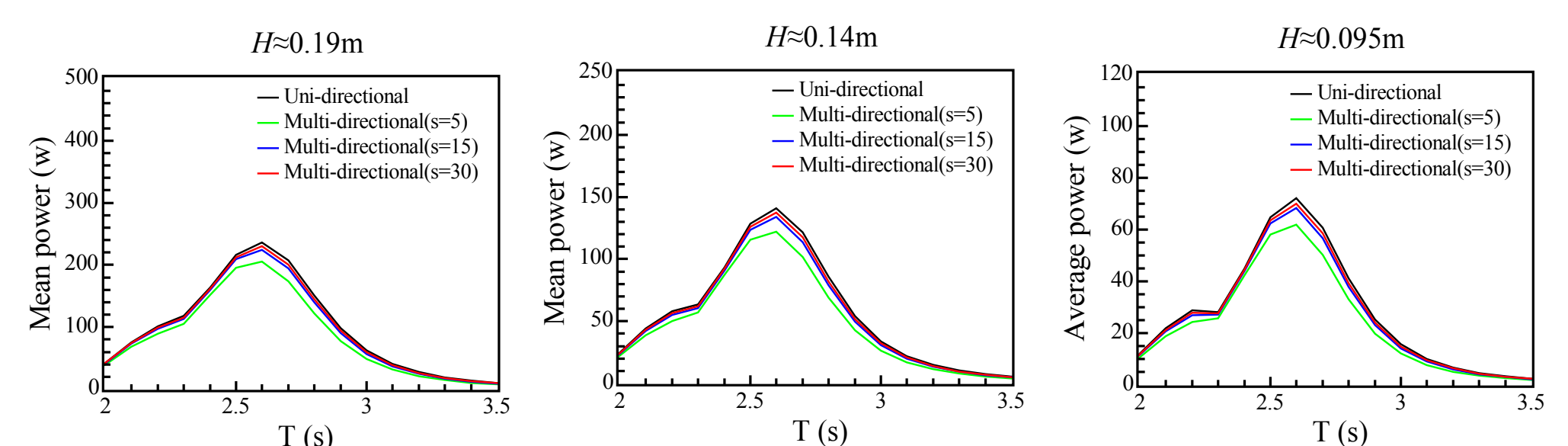
Here $|\theta_r|$ is the amplitude of relative rotation of the PTO element in numerical model of M4. B_{PTO} is damping coefficient for simplified PTO and $B_{PTO} = 2400 \text{ Nms}$.

Mean Power in Uni-directional Waves



Good agreements have been obtained in the comparisons between numerical results and experimental data when $C_d = 1.5$. In the model tests, the peak captured power is up to 234.3W for wave height $H \approx 0.19\text{m}$ at period $T = 2.5\text{s}$. It can be expected that in full scale the power generated by M4 has potential to reach 0.34MW with $H = 1.52\text{m}$ and $T = 7.1\text{s}$ although there maybe other energy losses during conversion.

Mean Power in Multi-directional Waves



The directional spreading of wave is described by using a spreading function of cosine shape $\cos^s(\theta_m)$, where s is the directional spreading parameter [1]. Three directional spreadings have been considered in present analyses ($s = 5, 15$ and 30) and $C_d = 1.5$. For $s = 5$, maximum reductions are obtained at $T = 2.6\text{s}$ which are about 13%. For $s = 15$ and 30 , no significant reductions are found in multi-directional waves.

References

1. P. Stansby, E. Carpintero Moreno, T. Stallard and A. Maggi, "Three-float broad-band resonant line absorber with surge for wave energy conversion," *Renewable Energy*, vol. 78, pp. 132-140, 2015.
2. Publications list of DIFFRACT, https://scholar.google.co.uk/citations?user=_Ec8JVUAAAAJ&hl.
3. L. Sun, R. Eatock Taylor and Y. S. Choo, "Multi-body dynamic analysis of float-over installations," *Ocean Engineering*, vol. 51, pp. 1-15, 2012.